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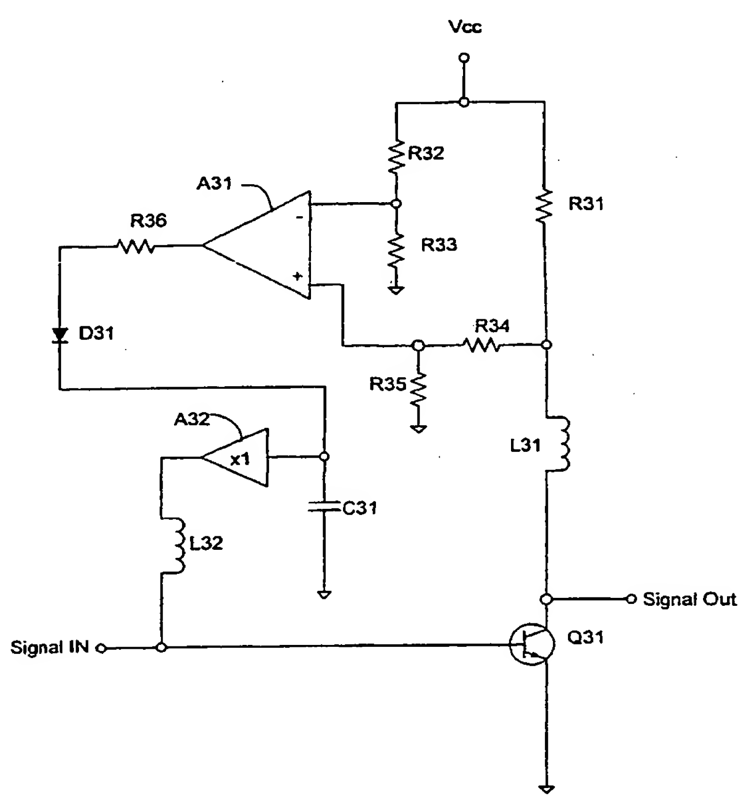
(54) Title: SYSTEM AND METHOD FOR AUTO-BIAS OF AN AMPLIFIER



(57) Abstract: The present invention provides a method and apparatus for autobiasing an amplifier. The invention is particularly useful in biasing non-linear amplifiers and amplifiers whose input signal may be amplitude modulated (AM). The auto-bias system of the present invention has an active bias feedback loop that continuously adjusts the bias condition of an amplifier to a wanted state during amplifier operation by monitoring a physical quantity indicative of the operating state of the amplifier and controlling the amplifier bias so as to control the amplifier operating point sufficiently to compensate for variations in amplifier electrical characteristics, amplifier load, amplifier temperature, and input signals. In the case of an AM input signal, the autobias system of the present invention may provide a sample and hold function so that the amplifier bias is the same during high power periods and low power periods, even though during high power periods the amplifier may be operating in a non-linear region. In one variation of the invention the amplifier may be an RF transistor, for example, a bipolar transistor, and may be used in a mobile cellular communications system. Further, the present amplifier auto-bias system eliminates the need for manually setting the amplifier bias during production and enables use of any transistor type in the amplifier.

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SYSTEM AND METHOD FOR AUTO-BIAS OF AN AMPLIFIER

BACKGROUND OF THE INVENTION

Technical Field of the Invention

The present invention relates generally to electrical amplification, and more particularly to an auto-bias system and method for an amplifier.

Description of the Related Art

Mobile cellular communications, like many other electronic applications, requires a bias circuit to bias an amplifier which is used, for example, in the transmitter of a cellular base station or mobile telephone. In one conventional RF amplifier using a bipolar transistor, the general bias method for the RF amplifier has been to set a fixed DC-voltage to the base of the transistor. The collector current of the RF transistor is controlled by way of adjusting the DC-voltage during the production process in manufacturing the device using, for example, a variable resistor and diode. Once the bias is adjusted and set in production the bias of the amplifier remains substantially the same unless manually altered in the filed. One such circuit is shown in Figure 1.

In the conventional amplifier shown in Figure 1, the base voltage of an RF transistor is set by transferring the knee voltage of the diode D1 to the base of the bipolar transistor Q1 via the coil L2. The base voltage of transistor Q1

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voltage so as to stabilize the amplifier operation as required by some applications. For example, one such temperature compensation circuit is provided by adding a positive temperature coefficient (PTC) resistor connected in series with VR1. This causes the total resistance from Vcc to D1 to increase when the temperature rises, thus decreasing the base voltage of Q1 and collector current of Q1. However, even with the addition of such a temperature compensation circuit the conventional method of biasing results in a bias condition that tends to drift as a function of temperature, because the temperature compensation circuit is not exactly at the same temperature as the RF transistor Q1 at various times during circuit operation given that the RF transistor Q1 and the temperature compensation circuit are in different physical locations. Third, the thermal matching of the transistor Q1 and diode D1 pair has unit to unit variation so even though the transistor Q1 and diode D1 pair are matched as best as possible at their nominal values, the use of a particular transistor for transistor Q1 and a particular diode for diode D1 does not generally result in perfect thermal matching. Fourth, in high power conditions the RF transistor Q1 is at higher temperature than the diode D1 and causes more inaccuracy to the thermal compensation (i.e., power related temperature transients). Finally, the conventional bias method requires that during the design phase every different transistor type (e.g., transistors having different electrical and temperature characteristics) that is to be used as the transistor Q1 in the amplifier requires a different individual thermal

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system eliminates the need for manually adjusting the amplifier bias during production and enables use of any transistor type in the amplifier.

According to one variation of the invention, an active bias feedback loop is provide which includes a bias measurement device connected to an amplifier transistor so as to measure a physical quantity, for example, a voltage, current, temperature etc. The measured physical quantity is provided to a control circuit which monitors the physical quantity and continuously adjusts its output according to variations in the physical quantity. The output of the control circuit (alternatively the output of the measurement device) is input to a sample and hold device, e.g., a capacitor, and to the bias circuit so as to vary the amplifier bias in a manner that will provide a relatively stable amplifier operating point in response to variation in the physical quantity being measured. Thus, the bias method of the present invention continuously adjusts the amplifier bias so as to improve the amplifier characteristics by maintaining a desired amplifier operating level.

According to another variation of the invention, a bias measurement is provided by measuring a current provided to an input terminal (e.g., collector) of an amplifier RF transistor. Measurement and control circuits includes a parallel set of series resistors, which act as voltage dividers, and a sample amplifier, which in conjunction operate to provide a varying voltage to a sample and hold capacitor based on a measured transistor input voltage. The sample and hold capacitor is connected to the input of an amplifier (e.g., a

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design for various particular transistor types or transistors from different manufacturers; (2) eliminating the need to tune the amplifier in production because it is automatically tuned based on the design of the auto-bias system; (3) eliminating the need for providing an automatic temperature compensation feature because such compensation is inherent in the auto-biasing system of the present invention; and (4) eliminating the long term drift effects of bias parameters as well as a lag in the bias tracking that may result due to rapid amplifier loading.

The invention is also particularly useful for RF amplifiers and for biasing amplifiers that must operate both in linear and non-linear regions. As a result of using the auto-bias invention, the same desired transistor bias may be provided during both class-A operation and class-AB operation of the amplifier when using an AM or amplitude varying input signal.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing summary of the invention, as well as the following detailed description of preferred embodiments, is better understood when read in conjunction with the accompanying drawings, which are included by way of example, and not by way of limitation, with regard to the claimed invention.

Figure 1 illustrates a conventional RF amplifier bias circuit.

Figure 2 illustrates a first embodiment of an auto-bias amplifier

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22. The measurement device 28 is coupled to the amplifier 21 and to the control device 24 and may be coupled to power supply 22. The control device 24 may be further coupled to the sample and hold device 26 and may be coupled to the bias device 30. The sample and hold device 26 is further coupled to the bias device 30. In its simplest form, the invention may include a measurement circuit and an active bias circuit that may include a sample and hold device.

In operation, the measurement device 28 measures a physical quantity, for example, an operating parameter such as a voltage, current, temperature etc., which is useful in controlling amplifier operation via the active bias feedback loop. The measurement provided by the measurement device 28 is, for example, a bias measurement, and is monitored by control 24. Control device 24 continuously adjusts its output in response to variations in the monitored measurement so as to maintain a particular desired bias level to the amplifier 21 via the sample and hold device 26 and the bias device 30. As such, any variation in the measured value will translate into a desired variation of the amplifier bias so that the amplifier maintains an optimum operating point that provides optimum amplifier electrical characteristics based on particular levels of current, temperature, power, etc., experienced by the amplifier during operation. As a note, the arrows illustrated in Figure 2 are provided for ease of understanding and are not intended to limit the invention. One skilled in the art understands that the active bias feedback loop of the

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An input signal to be amplified, Signal IN, is coupled to the base of transistor Q31 and the output signal of the amplifier is coupled to the collector of the transistor Q31. In GSM applications transistor Q31 may be an RF transistor and more particularly may be a bipolar transistor, a MOSFET, LDMOS, or GASFET, etc.

Resistors R31...R35 and amplifier A31 form a differential amplifier circuit for measuring the collector current of Q1. A power supply V_{CC} is coupled to transistor Q31 through resistor R31 and coil L31. Two voltage divider circuits are provided in parallel and are coupled between V_{CC} and ground. Series resistors R32 and R33 are coupled to V_{CC} and ground and an input of amplifier A31. Series resistors R34 and R35 are coupled to V_{CC} (via R31) and ground and a different input of amplifier A31. Amplifier A31 may be, for example, an operational amplifier. A31 may also have a feedback resistor between its negative (-) and output terminals.

The output of amplifier A31 is coupled to resistor R36, which is coupled to diode D31. Diode D31 is coupled to one terminal of capacitor C31 and amplifier A32. Capacitor C31 is coupled at its second terminal to ground. The output of amplifier A32 is coupled to the base of transistor via coil L32. Amplifier A32 may be, for example, a unity amplifier, or any type of amplifier that will provide a desired amplifier bias voltage given a voltage stored in capacitor C31. As illustrated in this preferred embodiment the active auto-bias feedback loop includes resistors R31 - R36, amplifiers A31 and A32, diode

Q31 during class-A operation so as to achieve a desired collector current for transistor Q31. If the collector current is too low the voltage of the positive (+) input to amplifier A31 is high relative to the voltage of the negative (-) input to amplifier A31 and causes the output voltage of amplifier A31 to increase, thus causing the voltage of capacitor C31 and the bias of the base of transistor A31 to increase. The base voltage of transistor Q31 will increase and provide a corresponding increase in the collector current. The increased collector current causes the positive (+) input of amplifier A31 to reach the voltage of the negative (-) input. When a balanced condition is reached, for example during the class-A operation, a voltage that will provide the desired amplifier bias voltage to the base of transistor Q31 is stored in capacitor C31. Thus, the voltage of the capacitor C31 when using, for example, an unity amplifier for amplifier A32, equals the base voltage of the amplifier transistor Q31 during a period when little or no input signal amplitude is provided as Signal IN (e.g., low power period).

The capacitor C31 provides a sample and hold function in GSM operation so that the voltage stored in capacitor C31 when there is little or no input signal (e.g., lower power period) is used to hold the transistor base voltage at the desired transistor base bias voltage during the signal period (e.g., high power period). At the end of the low power period the base voltage of the transistor Q31 corresponds to the voltage of the desired collector bias current. During the high power signal period the amplifier transistor Q31

coupled at its emitter between resistor R41 and coil L41. A reference voltage Vref is coupled to the base of transistor Q42. The collector of transistor Q42 is coupled to one terminal of a capacitor C41 and the input of an amplifier A41. Capacitor C41 is coupled at a second terminal to ground. The output of amplifier A41 is coupled to the base of transistor Q41 via coil L42. Amplifier A41 may be, for example, a unity amplifier, or any type of amplifier that will provide a desired amplifier bias voltage given a voltage stored in capacitor C41. As illustrated in this preferred embodiment the active auto-bias feedback loop includes transistor Q42, capacitor C41, and amplifier A41.

In operation, if the collector current of transistor Q41 is too low the emitter voltage of transistor Q42 is high relative to the reference voltage Vref which causes the collector voltage of transistor Q42 to increase. The increase in voltage of the collector voltage of transistor Q42 results in increased output voltage from amplifier A41, i.e., the base voltage of transistor Q41 increases, until a corresponding increase in the collector current of transistor Q41 causes the emitter voltage of transistor Q42 to reach a balance condition (e.g., Vref + 0.7 volts). When a balance condition is reached during, for example, a period of little or no input signal to Signal In, (e.g., the class-A operation) and the desired amplifier bias voltage is provided to the base of transistor Q41, capacitor C41 will store the voltage indicative of the desired amplifier bias voltage. For example, when a unity amplifier is used for amplifier A41, the voltage of capacitor C41 (sample and hold capacitor) will equal the bias

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systems because the invention includes a sample and hold operation during the class-A period (e.g., low power) of an input signal to maintain the desired bias during a class-AB period (e.g., high power) of an input signal. The invention is well suited for applications in which the input signal has sufficient amplitude variation so that the sample and hold capacitor can store the desired amplifier bias during low signal periods and maintain the same relative bias level during high signal periods. Further, the invention may be used for any amplifier design regardless of the type of transistor used.

The invention is particularly useful for setting a amplifier bias in general because the bias control is automated and generally more accurate over time and temperature. Generally, the bias method of the present invention improves the amplifier characteristics, for example, current, temperature compensation, frequency response, and power. The invention is also particularly useful for RF amplifiers and even more useful for biasing amplifiers that must operate in both linear and non-linear regions. As a result of using the auto-bias invention, the same desired amplifier bias may be provided during both class-A operation and class-AB operation of the amplifier when using an AM or amplitude varying input signal. This is particular useful when the amplifier experiences rapid increased loading that results in a significant temperature change on an initial signal input after an inactive period. For example, the present invention when used in a transmitter of a base station in a cellular communication system allows the amplifier bias

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WHAT IS CLAIMED IS:

1. An apparatus comprising:

a first amplifier; and

a feedback circuit coupled to said first amplifier that adjusts a bias level of said first amplifier, said feedback circuit including a sample and hold circuit.

2. The apparatus as claimed in claim 1, wherein said feedback circuit further includes a control circuit to control said adjustment of said bias level.

3. The apparatus as claimed in claim 2, wherein said feedback circuit further includes a bias circuit to drive an input of said first amplifier.

4. The apparatus as claimed in claim 3, wherein said feedback circuit further includes a measurement circuit for measuring a physical quantity related to operation of said first amplifier.

10. The apparatus as claimed in claim 8, wherein said first amplifier includes a second transistor.

11. The apparatus as claimed in claim 10, wherein said first amplifier is an RF amplifier and said second transistor is a bipolar transistor.

12. An apparatus comprising:

an amplifier; and

a means to auto-bias an input of said amplifier so that said input of said amplifier is continuously adjusted in at least one mode based on variations in an operating parameter of said amplifier..

13. The apparatus as claimed in claim 12, wherein said means to auto-bias an input of said amplifier includes a means for sampling a voltage during a low power mode and holding said voltage during a high power mode so as to sufficiently maintain said input at a bias as set according to said operating parameter.

17. The wireless communication system as claimed in claim 16, further comprising an amplifier coupled between said first transistor and said capacitor.

18. The wireless communication system as claimed in claim 16, further comprising a second transistor coupled between said first transistor and said capacitor.

19. A method for biasing an amplifier, comprising the steps of:

measuring an operating parameter of said amplifier so as to set said amplifier to a predetermined operating condition; and

biasing said amplifier based on said operating parameter so as to provide said predetermined amplifier operating condition regardless of a level of an input signal to said amplifier.

20. The method as claimed in claim 19, further comprising the steps of:

monitoring said operating parameter; and

controlling a voltage input to a sample and hold circuit so as to set a desired amplifier bias in all modes of operation.

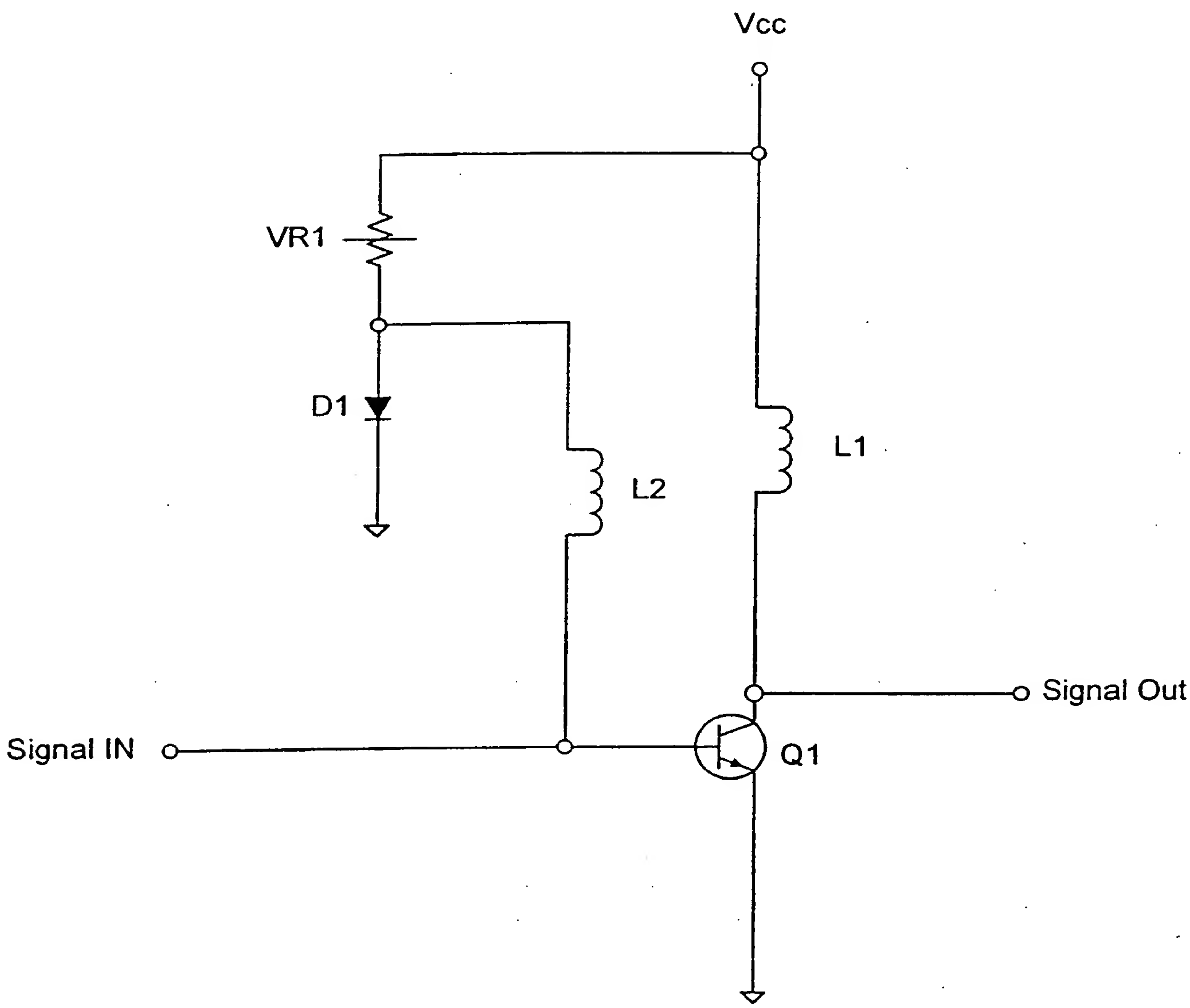

Figure 1
Prior Art

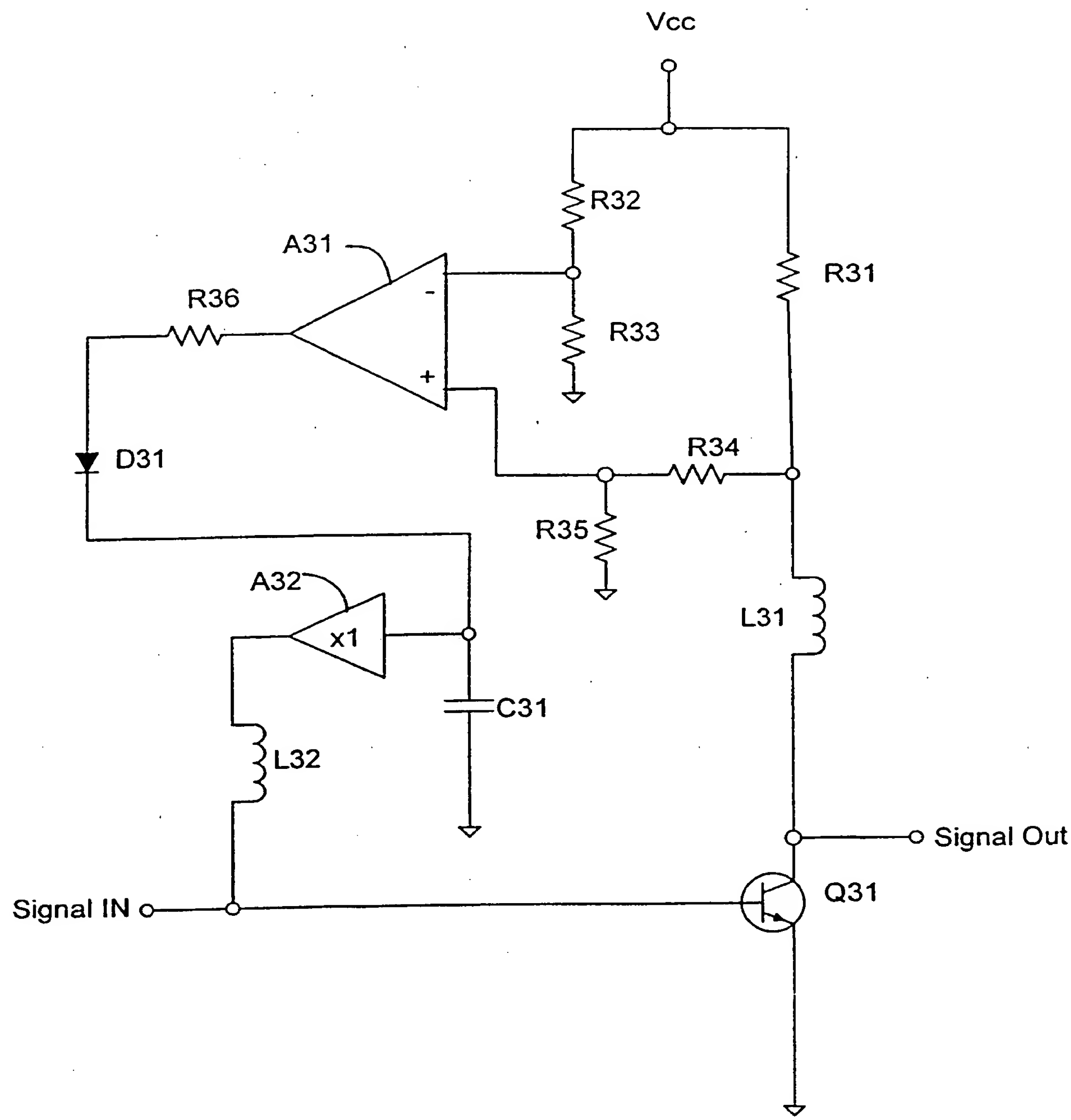
Vcc
R32
R31
A31
R36
R33
D31
R34
R35
A32
x1
L31
C31
L32
Signal Out
Q31
Signal IN

Figure 3

INTERNATIONAL SEARCH REPORT

Int tional Application No
PCT/IB 00/01799

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H03F1/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H03F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	MEGHDADI V ET AL: "MODELING OF SOLID STATE POWER AMPLIFIERS (SSPA) AND VALIDATION BY MEANS OF A SYSTEM SIMULATOR" ANNALES DES TELECOMMUNICATIONS - ANNALS OF TELECOMMUNICATIONS,CH,PRE SSES POLYTECHNIQUES ET UNIVERSITAIRES ROMANDES, LAUSANNE, vol. 53, no. 1/02, 1998, pages 4-13, XP000750640 ISSN: 0003-4347 page 5; figure 5 ---	1-7

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search	Date of mailing of the international search report
12 February 2001	20/02/2001

Name and mailing address of the ISA	Authorized officer
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Zeichen/Ref./Réf.	Anmeldung Nr./Application No./Demande n°./Patent Nr./Patent No./Brevet n°.
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Anmelder/Applicant/Demandeur/Patentinhaber/Proprietor/Titulaire FUJITSU LIMITED	

COMMUNICATION

The European Patent Office herewith transmits as an enclosure the European search report for the above-mentioned European patent application.

If applicable, copies of the documents cited in the European search report are attached.

☐ Additional set(s) of copies of the documents cited in the European search report is (are) enclosed as well.

The following specifications given by the applicant have been approved by the Search Division:

☒ abstract ☒ title

☐ The abstract was modified by the Search Division and the definitive text is attached to this communication.

The following figure will be published together with the abstract: 1

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If applicable under Article 10 Rules relating to fees, a separate communication from the Receiving Section on the refund of the search fee will be sent later.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IB 00/01799

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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 30 6546

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
P,A	WO 01 43277 A (NOKIA NETWORKS OY ;NOKIA INC (US)) 14 June 2001 (2001-06-14) * page 8, line 8 - page 9, line 20; figure 2 *	1	H03K6/04 H03F1/30

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

H03K
H03F

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
MUNICH	16 April 2002	Brown, J

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 01 30 6546

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0143277 A	14-06-2001	AU 1721701 A	18-06-2001
		WO 0143277 A1	14-06-2001

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